

UNITED STATES PATENT APPLICATION

FOR

Corrugated Shearwall

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BACKGROUND OF THE INVENTION

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Field of the Invention

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[0001] The present invention relates to a shearwall for opposing lateral forces on building walls, and in particular to a prefabricated shearwall including a central diaphragm having a corrugated or non-planar cross section to improve the ability of the shearwall to withstand lateral forces such as those generated in earthquakes, high winds, floods and snow loads.

Description of the Related Art

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[0002] Shearwalls were developed to counteract the potentially devastating effects of natural phenomena such as seismic activity, high winds, floods and snow loads on the structural integrity of light-framed constructions. Prior to shearwalls and lateral bracing systems, lateral forces generated during these natural phenomena often caused the top portion of a wall to move laterally with respect to the bottom portion of the wall, which movement could result in structural failure of the wall and, in some instances, collapse of the building. Shearwalls within wall sections of light-framed constructions provide lateral

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stability and allow the lateral forces in the wall sections to be transmitted through the shearwalls between the upper portions of the wall and the floor diaphragm or foundation of the building where they are dissipated without structural effect on the wall or building.

5 **[0003]** In constructions such as residences and small buildings, a lateral
bracing system typically includes vertical studs spaced from each other and
affixed to horizontal top and bottom plates. The bottom plate is typically
anchored to the floor diaphragm or foundation. The bracing system typically
10 further includes sheathing affixed to the studs, upper plate and/or lower plate to
increase structural response to lateral forces. The sheathing used is generally
oriented strand board (OSB) or plywood, but fiberboard, particleboard and
drywall (gypsum board) are also used. Alternatively or additionally, light-frame
construction wall sections may include prefabricated shearwall sections, which
15 can be positioned between the vertical studs and affixed to the studs and the top
and bottom connecting plates. The sheathing or prefabricated panels can also
be placed adjacent door and window frames to improve the response to lateral
forces at these locations.

[0004] A conventional prefabricated shearwall 20 is shown in the
perspective and cross-sectional views in Figs. 1 and 2. The shearwall includes
20 an interior diaphragm 22 formed of thin gauge sheet steel which is affixed to an
exterior wooden frame 24. The diaphragm is conventionally planar with the
edges along the length of the diaphragm being formed to respective lips 26 and
28. The lips 26, 28 allow the diaphragm to be affixed to the wooden frame.

[0005] While a prefabricated shearwall of the construction shown in Figs. 1
25 and 2 provides lateral force response and resistance, it has limitations with
respect to its lateral load bearing capabilities. There is, therefore, a need for an
improved shearwall capable of withstanding greater lateral loads.

SUMMARY OF THE INVENTION

[0006] It is therefore an advantage of the present invention to provide a shearwall having improved lateral load bearing characteristics relative to similarly sized shearwalls.

5 **[0007]** It is another advantage of the present invention to provide a shearwall having improved lateral load bearing characteristics without adding to the size or materials used relative to conventional shearwalls.

[0008] It is another advantage of the present invention to provide a shearwall having improved lateral load bearing characteristics which may be
10 easily retrofit into existing structures.

[0009] These and other advantages are provided by the present invention which in preferred embodiments relates to a prefabricated shearwall including a central diaphragm having a height generally defined by top and bottom edges, and a width generally defined by a pair of end sections. The diaphragm further
15 includes at least one corrugation extending in the height direction at least partially between the top and bottom edges. The corrugation increases the cross-sectional area and ductility of the diaphragm in the lateral direction in comparison to conventional shearwalls, and further improves the resistance of the shearwall to lateral forces such as those generated in earthquakes, high winds, floods and
20 snow loads.

[0010] In embodiments of the invention, the shearwall may further include a pair of reinforcing chords affixed to the end sections of the central diaphragm. The chords may be formed of 2 inch x 4 inch wooden studs having a height equal to that of the central diaphragm. The chords further improve the resistance of the
25 shearwall to lateral forces.

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[0013]

[0014]

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- [0016]** FIGURE 3 is a perspective view of a prefabricated shearwall according to an embodiment of the present invention;
- [0017]** FIGURE 4 is a cross-sectional view through line 4-4 of Fig. 3 showing the prefabricated shearwall according to the present invention;
- 5 **[0018]** FIGURE 5 is an exploded perspective view of the prefabricated shearwall according to the present invention;
- [0019]** FIGURE 6 is a perspective view of a shearwall according to the present invention mounted to an underlying support surface such as a building foundation;
- 10 **[0020]** FIGURE 7 is a front view of a shearwall according to an alternative embodiment of the present invention where the size and shape of the corrugation changes from the top edge to the bottom edge of the shearwall;
- [0021]** FIGURE 8 is a cross-sectional view through line 8-8 of Fig. 7;
- [0022]** FIGURE 9 is a cross-sectional view through line 9-9 of Fig. 7;
- 15 **[0023]** FIGURE 10 is a cross-sectional view through line 10-10 of Fig. 7;
- [0024]** FIGURE 11 is a front view of a shearwall according to a further alternative embodiment of the present invention similar but inverted with respect to Fig. 7;
- 20 **[0025]** FIGURE 12 is a front view of a shearwall according to a further alternative embodiment of the present invention where the size and shape of the shearwall changes from the top edge to the bottom edge of the shearwall;

- [0026]** FIGURE 13 is a front view of a shearwall according to a further alternative embodiment of the present invention where the size and shape of the corrugation changes from the top edge to the bottom edge of the shearwall;
- [0027]** FIGURE 14 is a cross-sectional view through line 14-14 of Fig. 13;
- 5 **[0028]** FIGURE 15 is a cross-sectional view through line 15-15 of Fig. 13;
- [0029]** FIGURE 16 is a cross-sectional view through line 16-16 of Fig. 13;
- [0030]** FIGURE 17 is a front view of a shearwall according to a further alternative embodiment of the present invention where the shearwall has cutout sections in the surface of the central diaphragm;
- 10 **[0031]** FIGURE 18 is a cross-sectional view through line 18-18 of Fig. 17;
- [0032]** FIGURE 19 is a cross-sectional view through line 19-19 of Fig. 17;
- [0033]** FIGURES 20 through 24 are cross-sectional views of alternative embodiments of the central diaphragm which may be used in the present invention;
- 15 **[0034]** FIGURE 25 is a cross-sectional view from the same perspective as Figs. 20 through 24, further including an embossment;
- [0035]** FIGURE 26 is a side view of an embossment shown in Fig. 25;
- [0036]** FIGURE 27 is a cross-sectional view from the same perspective as Figs. 20 through 24, further including an inwardly facing stiffening lip;
- 20 **[0037]** FIGURE 28 is a cross-sectional view from the same perspective as Figs. 20 through 24, further including an outwardly facing stiffening lip;

[0038] FIGURES 29 and 30 are cross-sectional views of a further alternative embodiment of the present invention; and

[0039] FIGURE 31 is a front view of the embodiment of the present invention shown in Figs. 29 or 30.

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DETAILED DESCRIPTION

[0040] The present invention will now be described with reference to Figs. 3 through 31, which in embodiments relate to a prefabricated shearwall panel including a central diaphragm having a non-planar cross-section to improve the lateral load bearing characteristics of the panel. It is understood that the present invention may be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather these embodiments are provided so that this disclosure will be thorough and complete and will fully convey the invention to those skilled in the art. Indeed, the invention is intended to cover alternatives, modifications and equivalents of these embodiments, which are included within the scope and spirit of the invention as defined by the appended claims. Furthermore, in the following detailed description of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be clear to those of ordinary skill in the art that the present invention may be practiced without such specific details.

[0041] Referring now to Figs. 3 through 4, there is shown a prefabricated shearwall 100 according to the present invention. The shearwall 100 includes a central diaphragm 102 having a height, width, and depth, each perpendicular to each other and denoted as h, w and d, respectively, in Fig. 4. In embodiments of the present invention, the central diaphragm 102 includes a top edge 101 and a bottom edge 103 generally defining the height of the central diaphragm, and a pair of end sections 104 and 106 generally defining the width of the central

diaphragm. The diaphragm 102 further includes a corrugation 108 defined by rear planar sections 110 and 112, angled sections 114 and 116, and front planar section 118. While the corrugation 108 is shown comprised of planar sections joined at angles with respect to each other, it is understood that the corrugation
5 108 may have different configurations in alternative embodiments. As used herein, a corrugation may be any ridge, groove or angle formed in central diaphragm 102 extending in the height direction at least partially between the top edge 101 and the bottom edge 103. The ridge, groove or angle lies in between the end sections 104, 106 in a plane different from that of an adjacent section
10 which also extends in the height direction between the top and bottom edges 101, 103 in between the end sections 104, 106.

[0042] Some alternative embodiments of the central diaphragm are shown in Figs. 7 through 28 and discussed hereinafter. In addition to adding increased resistance to compressive loads (*i.e.*, those parallel to the diaphragm height), the
15 corrugation 108 increases the cross-sectional area and its ability to withstand lateral forces (*i.e.*, those parallel to the diaphragm width). Moreover, the corrugation 108 provides increased ductility to the shearwall in the lateral direction.

[0043] In embodiments of the present invention, the central diaphragm may
20 have an overall height of 93¼ inches, an overall width of 12 inches, and a depth of 2½ inches. It is understood that each of these dimensions may be varied in alternative embodiments, both proportionately and disproportionately with respect to each other. For example, in one alternative embodiment, the central diaphragm may have an overall width of 18 inches. Each of the sections 104,
25 106 and 110 through 118 is preferably the same height. In embodiments where the overall width is 12 inches, end sections 104 and 106 may each be 2½ inches wide, rear planar sections 110 and 112 may each be 3 inches wide, the angled sections 114 and 116 may each be 4¼ inches wide, and the front planar section

118 may be 1½ inches wide. It is understood that each of these dimensions for the sections 104, 106 and 110 through 114 may vary in alternative embodiments, both proportionately and disproportionately with respect to each other. In embodiments of the present invention, the central diaphragm 102 may be formed
5 of 7-gauge sheet steel (0.1875 inches). Other gauges, such as for example 10-gauge sheet steel, and other materials of comparable strength and rigidity may be used in alternative embodiments. One such alternative material may be expanded metal.

[0044] In a preferred embodiment, the rear planar sections 110, 112 may be
10 coplanar with a back edge of the diaphragm 102 and front planar section 118 may be coplanar with a front edge of the diaphragm 102 so that the corrugation 108 traverses the entire depth of the central diaphragm. As explained in greater detail below, the corrugation 108 need not traverse the entire depth of the central diaphragm in alternative embodiments.

[0045] Referring now to Figs. 5 and 6, when installed into a wall, the top and
15 bottom edges 101 and 103 of the central diaphragm lie within U-shaped channels 119 and 121, respectively. In embodiments of the invention, both U-shaped channels may be formed of ¼ inch steel plate bent into a U shape. Each channel 119, 121 may be as long as the central diaphragm is wide. The uppermost
20 surface of channel 119 and the lowermost surface of channel 121 shown in Fig. 5 may be 3 inches wide. The front and back edges of the channels may extend a few inches over the top and bottom of the central diaphragm, and the front and back edges may include scallops to facilitate fastening of the bolts securing the central diaphragm to the top plate and underlying surface as explained
25 hereinafter. The U-shaped channels 119, 121 may be omitted in alternative embodiments, in which case the top and bottom edges of the central diaphragm may attach directly to the top and bottom plates of the wall.

[0046] In embodiments of the present invention, the shearwall 100 may further include a pair of reinforcing chords 120 and 122 affixed to the end sections 104 and 106, respectively. The chords may be formed of wood, such as for example sawn lumber from lumber groups including spruce-pine-fir, Douglas
5 fir-larch, hem-fir and southern pine. The chords 120, 122 may alternatively be formed of engineered lumber, such as glulam and wood composites. Other types of wood are contemplated. The chords may have a height equal to that of the central diaphragm 102 and channels 119 and 121 together, and may be 4 inches wide by 2 inches deep. Various affixing mechanisms may be used to affix
10 the chords to the central diaphragm, such as for example a plurality of ¼ inch x 1½ inch Simpson Strong-Drive® screws. Other types of screws and affixation methods are contemplated. The screws in one embodiment may be provided in each chord along a single column and spaced apart 6 to 12 inches from each other. It is understood that the screws may be provided in more than one
15 column, or not aligned in a column, down the length of the chords 120, 122, and may be spaced apart more or less than 6 to 12 inches in alternative embodiments.

[0047] Affixation of the chords to the central diaphragm as described above further improves the resistance of shearwall 100 to lateral forces. While a single
20 chord is shown on each side of the central diaphragm, it is understood that more than one chord may be provided at each end. For example, 2 to 4 (or more) such chords may be affixed together and mounted to each side of the central diaphragm. It is also understood that chords of less than 2 inches deep and 4 inches wide may be used in alternative embodiments. Sheathing (not shown)
25 may be affixed over the front and back surface of the central diaphragm and chords, and affixed to the chords by a variety of affixing mechanisms including Simpson Strong-Drive® screws. It is further understood that the chords 120, 122 may be omitted in alternative embodiments.

- [0048]** Shearwall 100 further includes a sill plate 124 affixed to the bottom of the central diaphragm. This allows shearwall 100 to have a lower load bearing surface with a sufficient surface area to allow distribution of the shearwall compressive forces over a sufficiently large area on the underlying floor diaphragm or foundation. If the compressive forces from the shearwall are concentrated, for example in a situation where the bottom plate is small or is shaped with channels so that only a portion of the bottom plate lies in contact with the underlying support surface, the resulting compressive forces can damage or cause failure in the underlying support surface.
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- [0049]** Accordingly, sill plate 124 is provided as a flat plate with a relatively large surface area. The plate 124 has a length which is preferably equal to that of the central diaphragm and the chords 120 and 122 together, and a width that is equal to the width of the chords 120 and 122. This width dimension is greater than the width of the U-shaped channel 121 in embodiments of the present invention. In such embodiments, this provides a sill plate which is 16 inches long and 4 inches wide. It is understood that the length and/or width of plate 124 may be larger in alternative embodiments. For example, in embodiments of the invention not including chords 120, 122 and/or channel 121, the footprint of the sill plate may be the same size as the footprint of the central diaphragm.
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- [0050]** Sill plate is also rigid enough to allow even distribution of any localized compressive forces from the shearwall 100. In one embodiment of the present invention, the sill plate 124 is formed of $\frac{1}{2}$ inch thick steel. In embodiments of the invention, sill plate 124 may be affixed within channel 121 by affixation methods such as welding. The rigidity of the sill plate 124 as well as the rigid affixation of the sill plate 124 to the channel 121 further prevents buckling of the shearwall under laterally applied loads. It is understood that sill plate 124 may have thicknesses other than $\frac{1}{2}$ inch in alternative embodiments.
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5 **[0051]** It is a further feature of the sill plate 124 to underlie the chords 120, 122, thereby preventing their contact with the underlying support surface. In embodiments of the present invention where shearwall 100 is mounted on a foundation, the sill plate 124 isolates the chords from wetness and moisture from the foundation which may otherwise weaken and erode the chords. The provision of the sill plate 124 under the chords also allows the compressive forces exerted specifically by the chords to be evenly distributed over the sill plate and onto the underlying support surface as described above.

10 **[0052]** Referring now specifically to Fig. 6, there is shown a perspective view of the shearwall 100 mounted on an underlying support surface 150. In the embodiment shown, underlying support surface 150 comprises a concrete building foundation, but it is understood that underlying support surface 150 may be any surface on which a conventional shearwall may be located, including for example a floor diaphragm on the building foundation or a floor diaphragm on a top plate of a lower floor. The shearwall is fastened to the underlying support surface 150 by means of anchors 152 (partially shown in Fig. 6) protruding up through aligned holes formed in the sill plate 124, channel 121 and the bottom of the central diaphragm 102. The bolts are then fastened over threaded ends of anchors 152 to anchor the shearwall to the underlying support surface. It is understood that shearwall 100 may be anchored to the underlying support surface by other anchoring mechanisms in alternative embodiments, such as for example by strap anchors, mudsill anchors, retrofit bolts, foundation plate holdowns, straps, ties, nails, screws, framing anchors, ties, plates, straps or a combination thereof.

25 **[0053]** Shearwall 100 may similarly include openings in the top edge of the central diaphragm 102 and channel 119 for affixation to a top plate of a wall as by bolts or other anchoring mechanisms described above. As also indicated above, shearwall 100 is prefabricated so that it may be easily located within a

wall in any desired location simply by affixing the shearwall to the underlying support surface and top plate. The shearwall may be installed initially during construction of a building, or retrofit after completion of construction.

5 **[0054]** Shearwall 100 including corrugated central diaphragm 102 is capable of withstanding greater lateral loads in comparison to conventional shearwalls. Moreover, the corrugation(s) improve the ductility of the shearwall in the lateral direction.

10 **[0055]** Up to this point, the corrugation 108 has been disclosed as having constant dimensions between the top edge 101 and the bottom edge 103. That is, the intersection between the rear planar section 110 and angled section 114, and the intersection between the rear planar section 112 and angled section 116, form lines that extend vertically between the top and bottom edges parallel to each other. Similarly, the intersections between the angled sections 114, 116 and the front planar section 118 form lines that extend vertically between the top
15 and bottom edges parallel to each other.

20 **[0056]** In an alternative embodiment of the present invention shown in the front view of Fig. 7 and the cross-sectional views of Figs. 8-10, the intersections between the various sections forming the corrugation need not be vertical or parallel to each other. In particular, the central diaphragm 202 shown in Fig. 7 includes a corrugation 208 defined by rear planar sections 210 and 212, angled sections 214 and 216, and front planar section 218. The intersection lines 220 and 222 between the rear planar sections and the angled sections slope inward from the bottom edge to the top edge. Similarly, the intersection lines 224 and 226 between the angled sections and the front planar section slope inward from
25 the bottom edge to the top edge. The result, as shown in the cross-sections of Figs. 8 through 10 along the length of the central diaphragm, is that the corrugation gets larger from the top edge to the bottom edge.

[0057] Fig. 11 is similar to Fig. 7 but inverted so that the intersection lines 220 and 222 between the rear planar sections and the angled sections slope outward from the bottom edge to the top edge. Similarly, the intersection lines 224 and 226 between the angled sections and the front planar section slope outward from the bottom edge to the top edge. Fig. 12 is similar to Fig. 7 but rear planar sections 210 and 212 are omitted so that the size and shape of the shearwall changes from the top edge to the bottom edge of the shearwall.

[0058] In addition to lateral force resisting characteristics of the shearwall 100 shown in Figs. 3-6, providing the bends between the various sections at angles that slope inward or outward from bottom to top provides even greater lateral force resistance, as there is a lateral component to the various bends between the sections. The lateral component to the various bends further resists movement in the lateral direction, and further improves the resistance of the shearwall to lateral loads.

[0059] Although not shown in Figs. 7 through 12, the shearwall shown therein may include the channels 119, 121, the chords 120, 122 and the sill plate 124 described above.

[0060] Figs. 13 through 16 are similar to Figs. 7 through 10, except that the corrugation 308 of Figs. 11 through 14 does not extend the entire length between the top and bottom edges of the central diaphragm. Instead, the corrugation begins at the bottom edge and the intersection lines between the various sections 310, 314, 316 and 318 slope inward until the corrugation ends at a point 320 between the top and bottom edges. Again, the shearwall of Figs. 13 through 16 would preferably include the channels 119, 121, the chords 120, 122 and the sill plate 124 described above. However, it is contemplated that the chords and/or the sill plate may be omitted in alternative embodiments.

[0061] In a further alternative embodiment of the present invention shown in Figs. 17 through 19, the central diaphragm may include apertures 260 provided through the surface of the diaphragm. The apertures may be various shapes and sizes in alternative embodiments, and may be formed in the diaphragm before or
5 after the corrugation is formed. The shapes may be oval, oblong, circular, quadrilateral, polygon or irregular from the front view in alternative embodiments. The size may also vary such that the aperture 260 extends as far out as the rear planar surfaces 210, 212 (as shown in Fig. 17), out as far as the angled sections 214, 216, or be provided only through the front planar section 218. Moreover,
10 while three such apertures 260 are shown in Fig. 17, the number of apertures 260 may be less than or greater than three in alternative embodiments. The apertures can be used to reduce the overall strength of the central diaphragm in such a way so that the shearwall 100 yields under lateral loads before an underlying support structure such as the foundation.

[0062] Up to this point, embodiments of the present invention have been shown as including a central diaphragm with a single corrugation 108, 208 or 308 as shown in Figs. 3 through 19. However, it is understood that the central diaphragm may have a non-planar cross-section in shapes other than a single corrugation in alternative embodiments of the invention. For example, as shown
20 in the cross-sectional view of Fig. 20, the central diaphragm may include a plurality of corrugations. While Fig. 20 shows 2 such corrugations, it is understood that more than 2 corrugations may be provided in further alternative embodiments. Fig. 21 shows a further embodiment where there is a single corrugation of constant shape from the top edge to the bottom edge, but the front
25 planar section 218 lies between the planes of the front and back edge of the central diaphragm. It is understood that the embodiments of Figs. 20 and 21 may be combined so that the central diaphragm includes a plurality of corrugations, each having a front planar section which lies between the planes of

the front and back edge of the central diaphragm. The embodiments of Figs. 20 and 21 may also be combined with the embodiments of Figs. 7 through 19.

5 **[0063]** As shown in Fig. 22, a further alternative embodiment of the central diaphragm may include a corrugation formed by a combination of straight and rounded sections. As a further alternative shown in Fig. 23, the central diaphragm may include a plurality of rounded corrugations. Fig. 24 illustrates a further embodiment where the angled sections 114, 116 are formed at right angles to the rear planar sections 112, 114 and the front planar section 118. These embodiments may be combined with any of the embodiments shown in
10 Figs. 7 through 19.

[0064] Figs. 25 and 26 show a further embodiment of the present invention including one or more embossments 270 formed in one or more surfaces of the central diaphragm to add strength to the diaphragm. While shown in end section 106, it is understood that the one or more embossments 270 may alternatively or
15 additionally be formed in opposite end section 104, or sections 112 through 118, in alternative embodiments. As shown in Fig. 26, when vertically oriented, the embossment(s) 270 may extend over a portion of sections 104, 106, and/or 112 through 118. Alternatively, the embossment(s) may extend substantially the entire length of the sections. While shown as being vertically oriented in Figs. 25
20 and 26, it is understood that the one or more embossments may be oriented differently in alternative embodiments. For example, the embossments may be provided horizontally or at an angle between the horizontal and vertical. Moreover, the embossments may be provided in a cross-hatched or herringbone configuration. The one or more embossments 270 may be used in any of the
25 embodiments shown in Figs. 7 through 24.

[0065] Figs. 27 and 28 show a further embodiment of the present invention including stiffening lips 280 formed in the horizontally oriented edges of end

sections 104 and 106. The lips 280 may be formed inwardly as shown in Fig. 27, or the lips 280 may be outwardly as shown in Fig. 28. The stiffening lips 280 may be provided to add additional strength to the diaphragm 102, and may be used in any of the embodiments shown in Figs. 7 through 26.

5 **[0066]** Figs. 29 through 31 illustrate a further alternative embodiment of the present invention. According to this embodiment, the central diaphragm 102 may be comprised of separate end members 402 and 404, and a separate central section 406. Each end member may include end sections 406, rear planar sections 408 and angled sections 410 similar to the end sections, rear planar
10 sections and angled sections described above with respect to other embodiments. The end members may optionally have a portion of a front planar section 412 similar to a portion of the front planar section described above with respect to other embodiments. The central section 406 may be a single unitary piece of material, such as metal, that extends the length of the diaphragm and is
15 affixed to the angled sections 410 at the front plane of the diaphragm, or to the portions of the front planar sections 412 (as shown). The central section may be affixed by welding or other known affixation methods.

20 **[0067]** As an alternative to a single unitary piece of material that extends the length of the diaphragm, the central section 406 may be comprised of more than one piece as shown in Fig. 31. In such an embodiment, the central section may include a section 406a at a top of the diaphragm and a section 406b at a bottom of the diaphragm. Though not critical to the present invention, the section 406a may extend down 12 inches from the top of the diaphragm and the section 406b may extend up 36 inches from the bottom of the diaphragm. It is understood that
25 the lengths of sections 406a and 406b may vary in alternative embodiments, both proportionately and disproportionately to each other.

5 **[0068]** The embodiment shown in Figs. 29 through 31 allows the overall width of the shearwall 100 to be easily provided to different widths in the field simply by using a central section of differing widths. A shorter width central section (Fig. 29) will provide one overall width, while a larger width central section (Fig. 30) will provide another overall width. Thus, a shearwall 100 of the precisely needed width may be easily and quickly formed. The embodiment shown in Figs. 29-31 may be used in conjunction with the embodiments disclosed above with respect to Figs. 7 through 28.

10 **[0069]** Although the invention has been described in detail herein, it should be understood that the invention is not limited to the embodiments herein disclosed. Various changes, substitutions and modifications may be made thereto by those skilled in the art without departing from the spirit or scope of the invention as described and defined by the appended claims.